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RAINFALL FREQUENCY ANALYSIS FOR 1- TO 15-DAY DURATIONS IN THE BLACKLANDS OF TEXAS

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RAINFALL FREQUENCY ANALYSIS FOR 1- TO 15-DAY DURATIONS IN THE BLACKLANDS OF TEXAS[1]

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INTRODUCTION

Frequency analyses of rainfall amounts for durations up to 15 days for the Blacklands of Texas are presented in this report. Similar analyses in the past were generally limited to durations of 24 hours or less (2, 13).[2] The results of these analyses cannot, with safety, be extrapolated beyond the 24-hour duration. Now a need has developed for information on much longer durations for guidance on the design and operation of flood control reservoirs. Low release rates required to gain desired flood control may take days to discharge stored flood waters. During this time storm inflow may recur because weather conditions frequently result in a sequential occurrence of runoff-producing storms over a period greater than 1 day.

One analysis of interest is that of Kotz and Neumann (6), who utilized parameters of the gamma distribution to expand rainfall amounts from unit time to other durations, including the 15-day period. Their method required manipulation of long-term records and did not provide probable rainfall estimates for various recurrence intervals. Furthermore, new computations were necessary for each duration.

In the study reported here, U.S. Weather Bureau data were analyzed for stations in and adjacent to the Blacklands of Texas. Frequency analyses were applied to annual maximum rainfall amounts occurring in 1-, 2-, 4-, 7-, and 15-day periods. Data from the Agricultural Research Service gages at the Blacklands Experimental Watershed near Riesel, Tex., aided in the interpretation of analyses.

PROCEDURE

Blacklands Experimental Watershed Data

Recording rain gage data are available at the Blacklands Experimental Watershed near Riesel, Tex., for the period 1937-60. From these records the maximum rainfall amount for each year was determined for selected n-minute periods, not necessarily clock hours

[1] Soil and Water Conservation Research Division, Agricultural Research Service, USDA, in cooperation with the Texas Agricultural Experiment Station, Texas A & M University.

[2] Underscored numbers in parentheses refer to Literature Cited at the end of the report.

nor calendar days, ranging from 5 minutes to 15 days. The frequency of occurrence for the intervals was determined by the Gumbel procedure for fitting to the Fisher-Tippett Type I distribution (7).

Depth-duration-frequency curves are shown in figure 1. The expected rainfall amounts for various durations give some indication of the characteristics of storm recurrence. Rainfall amounts increase rapidly from the 5-minute to the 6-hour durations. The plotted points indicate little additional rainfall between 6 hours and 1 day, whereas a considerable increase is observed from 1 to 7 days. After the 7-day period, little rainfall occurs during an additional 8 days. The relative increase with time indicates that storms are generally of a maximum 6-hour duration. Frequently, storm conditions re-form on successive days for a week; generally after a week, the atmospheric conditions change such that little additional rainfall occurs during the second week.

The durations employed in the analysis of the Riesel data were the n-minute intervals containing the greatest rainfall. For example, the 2-day period was 2,880 minutes long and did not necessarily start at the beginning of a calendar day. Published daily precipitation totals for the United States (9, 10) are for calendar days, and the detailed data are not readily available for determining maximum rainfall for a 24-hour period, or multiples thereof. Since the rainfall amounts for n-minute durations were needed in this analysis, a way to determine them from calendar-day totals was developed.

Data from three rain gages at Riesel for a 24-year period (1938-61) were analyzed to compare annual maximum rainfall amounts for n-minute periods with annual maximum amounts for multiples of calendar days. Ratios of mean annual maximum n-minute to mean annual maximum calendar-day rainfall amounts were determined for each of the three locations for 1-, 2-, 4-, 7-, and 15-day durations. The means of the ratios for each duration at the three locations were determined and are shown in figure 2.

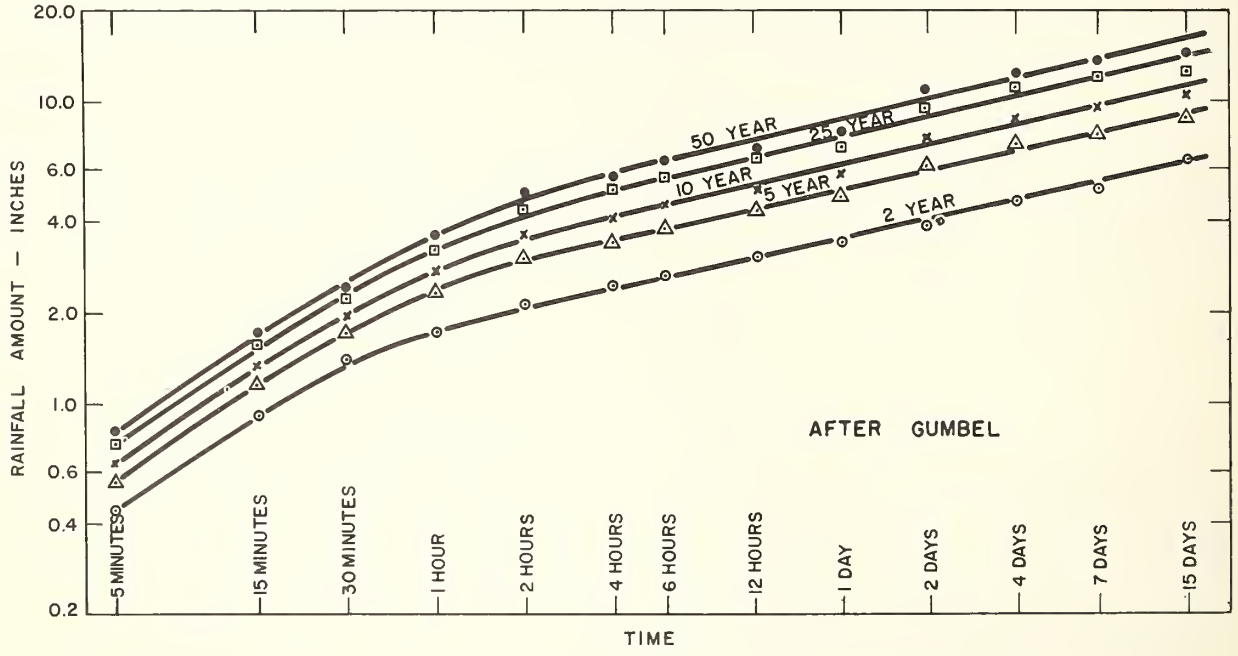

Figure 1.--Rainfall-frequency-duration, Blacklands Experimental Watershed, 1937-60.

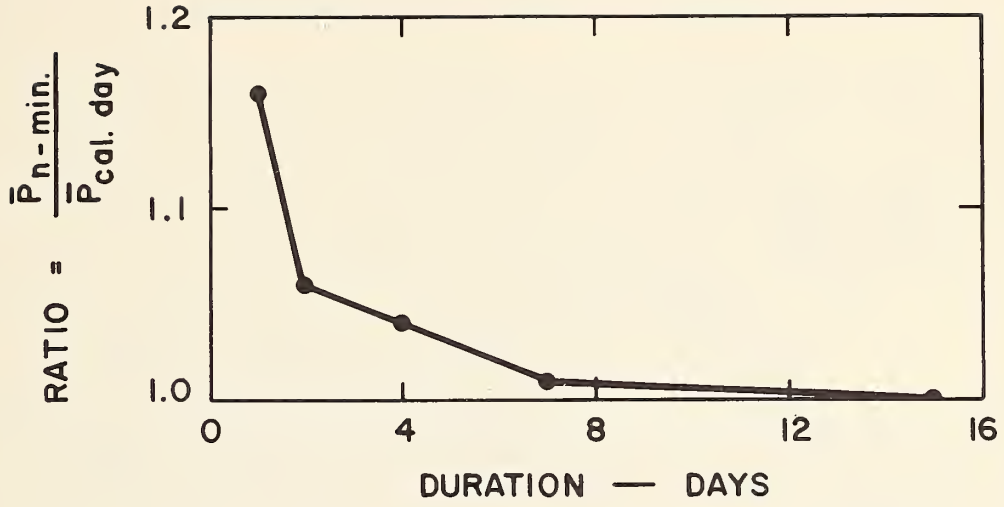

Figure 2.--Relation of annual maximum n-minute rainfall to annual maximum calendar-day rainfall by duration for the Blacklands of Texas.

The 1.16 ratio for 1-day duration is not significantly different from the 1.13 value determined by Hershfield (3). Since only three rain gage locations were used in this study as compared with the number studied by Hershfield, the comparative results for 1 day provide a high degree of reliability for other durations. Although the ratios are small for 2- and 4-day durations, an adjustment of data is necessary. The ratios for 7 and 15 days are not significantly greater than unity, and adjustments are not needed.

The ratios determined for 1-, 2-, and 4-day durations were used to estimate n-minute rainfall amounts from calendar day totals published by the Weather Bureau.

Weather Bureau Data

Locations

Maximum annual rainfall amounts for the selected time intervals were determined for 47 Weather Bureau reporting stations (9, 10). The locations, shown in figure 3, provided coverage of the Blackland Prairies and surrounding areas. The Blackland Prairies comprise almost 18,000 sq. mi. in central Tex. (1) and includes all or parts of 40 counties. The selected rain gage network provided an average coverage of 382 sq. mi. per gage.

Length of Record

Although the length of record varied for each location, at least 50 years of data were available for most reporting stations. Only 13 reporting stations had less than 50 years' record, and these were generally in the upper 40's. Particular attention was given to these 13 locations and there was little evidence of extreme events that would cause the data to be seriously biased.

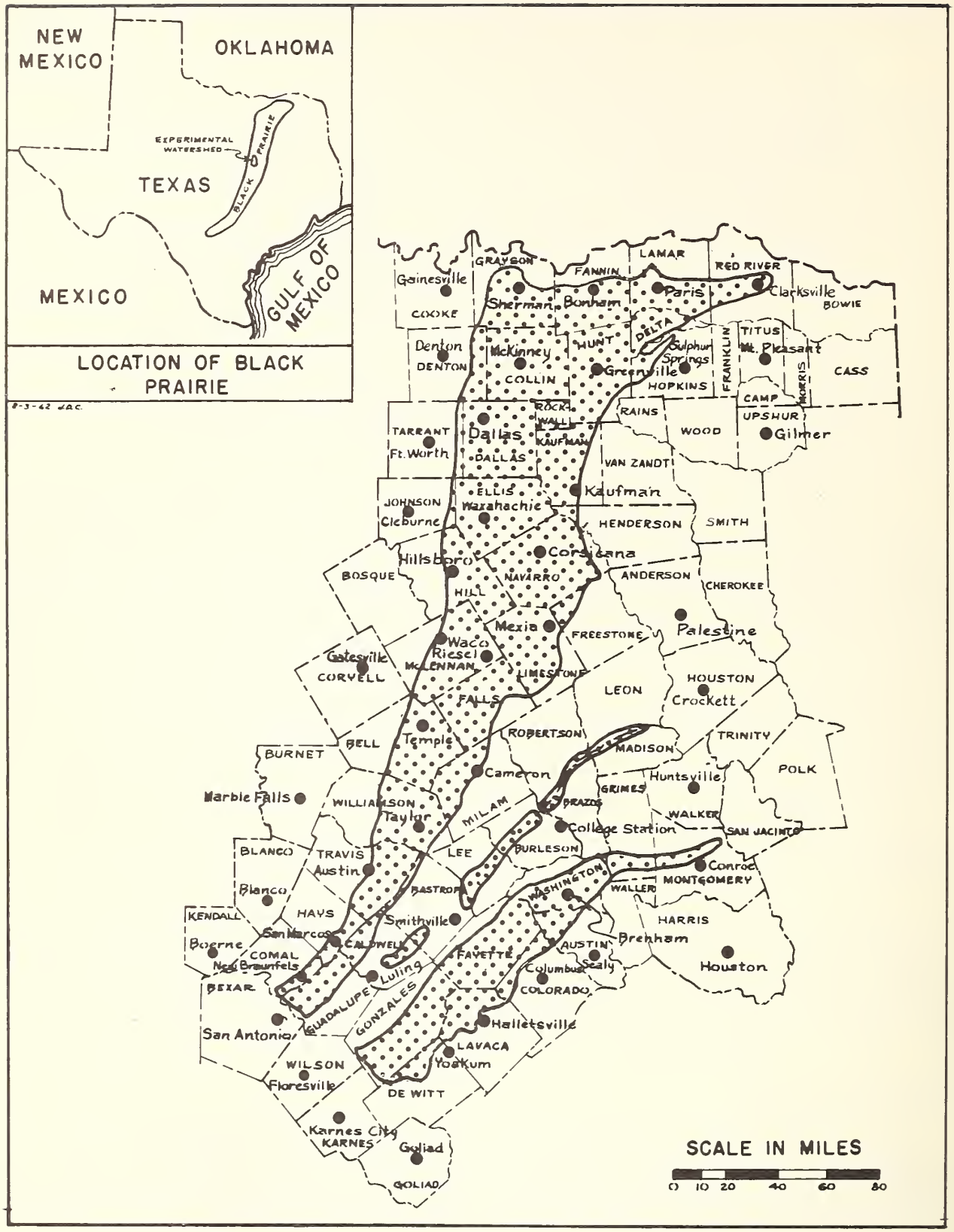

Figure 3.--Blackland Prairies and Weather Bureau reporting stations.

Analysis

The Gumbel procedure for fitting extreme-value data to the Fisher-Tippett Type I distribution (7) was used to determine rainfall probabilities for 1-, 2-, 4-, 7-, and 15-day periods for each location. The 1-, 2-, and 4-day values were adjusted by use of the ratios shown in figure 2. Regression equations were computed using the method of least squares (8). Typical data for each duration at one location are shown in figures 4 through 8. Rainfall amounts for 2- and 100-year recurrence intervals were determined for each duration at each location. Probability maps were constructed from the computed data for 2-year 1-day and 100-year 1-day rainfall and are shown in figures 9 and 10, respectively.

Data from all locations were used to determine linear relations between the 1-day and the 2-day, the 1-day and the 4-day, the 1-day and the 7-day, the 1-day and 15-day durations; and regression equations were developed. A graph based on these equations is shown on the right portion of figure 11, with 1-day rainfall on the ordinate and the 2-, 4-, 7-, and 15-day rainfall on the abscissa. The left portion of figure 11 is a Gumbel frequency chart which relates 1-day rainfall to return period.

The probability maps and the graphical relation are used together to determine rainfall amounts for any combination of durations from 1 to 15 days and recurrence intervals from 2 to 100 years. For example, an estimate of the 25-year rainfall at Dallas is made in the following manner. The 2-year 1-day rainfall amount, determined from the probability map of figure 9, is 3.8 inches and is plotted as point "A" in the graphical relationship of figure 11. The 100-year 1-day rainfall, determined from the probability map of figure 10, is 8.7 inches and is plotted as point "B" in figure 11. A straight line drawn between "A" and "B" intersects

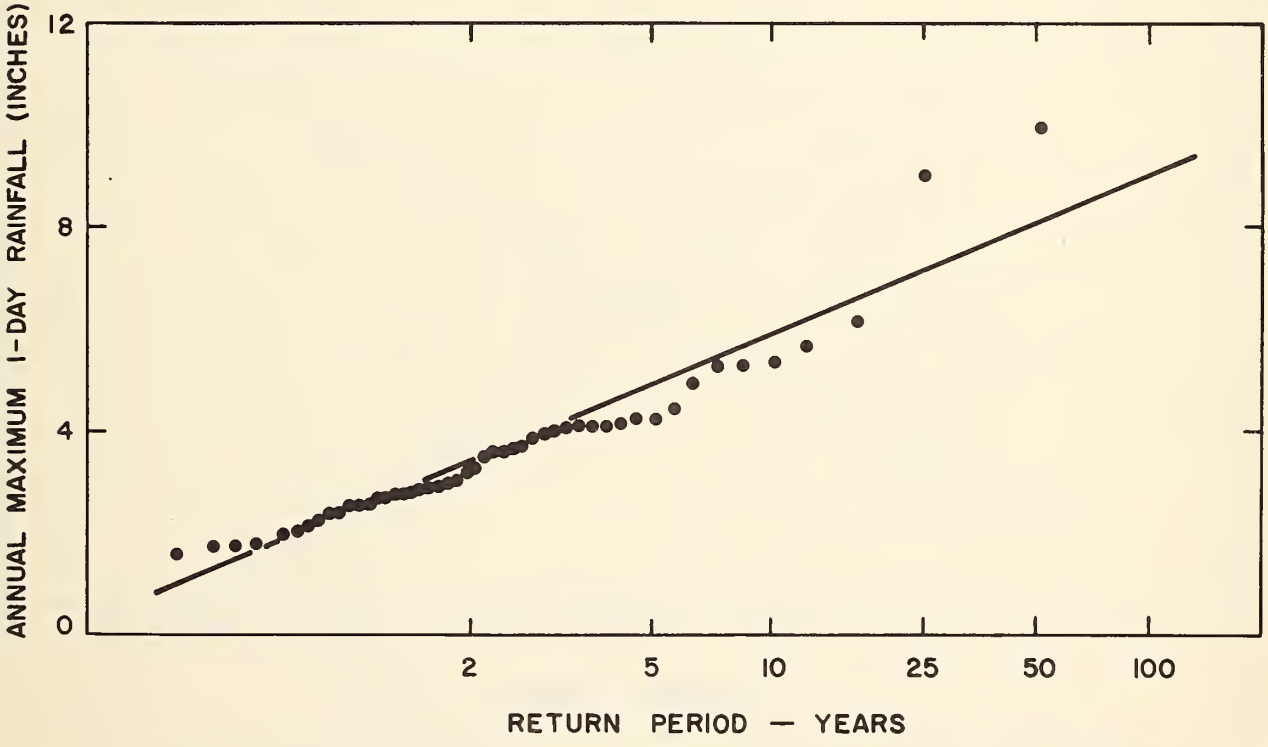

Figure 4.--Gumbel frequency of annual maximum 1-day rainfall at Fort Worth, Tex., 1912-61.

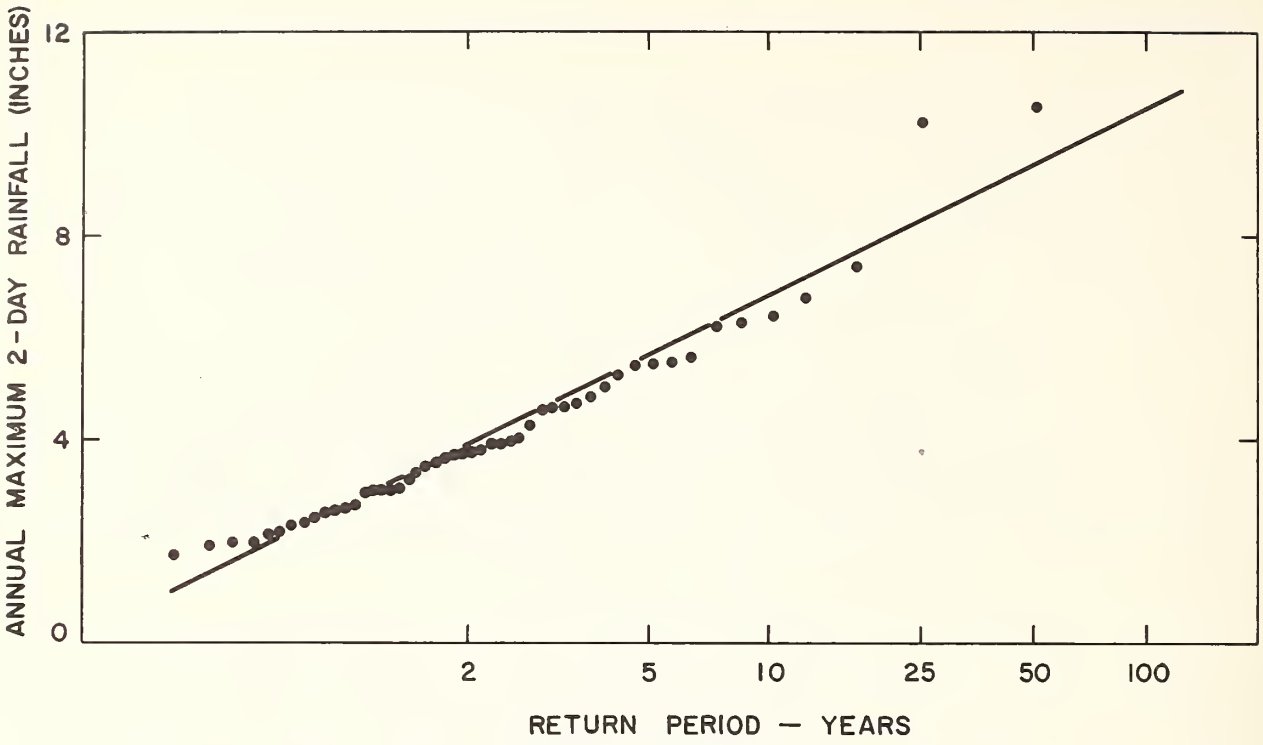

Figure 5.--Gumbel frequency of annual maximum 2-day rainfall at Fort Worth, Tex., 1912-61.

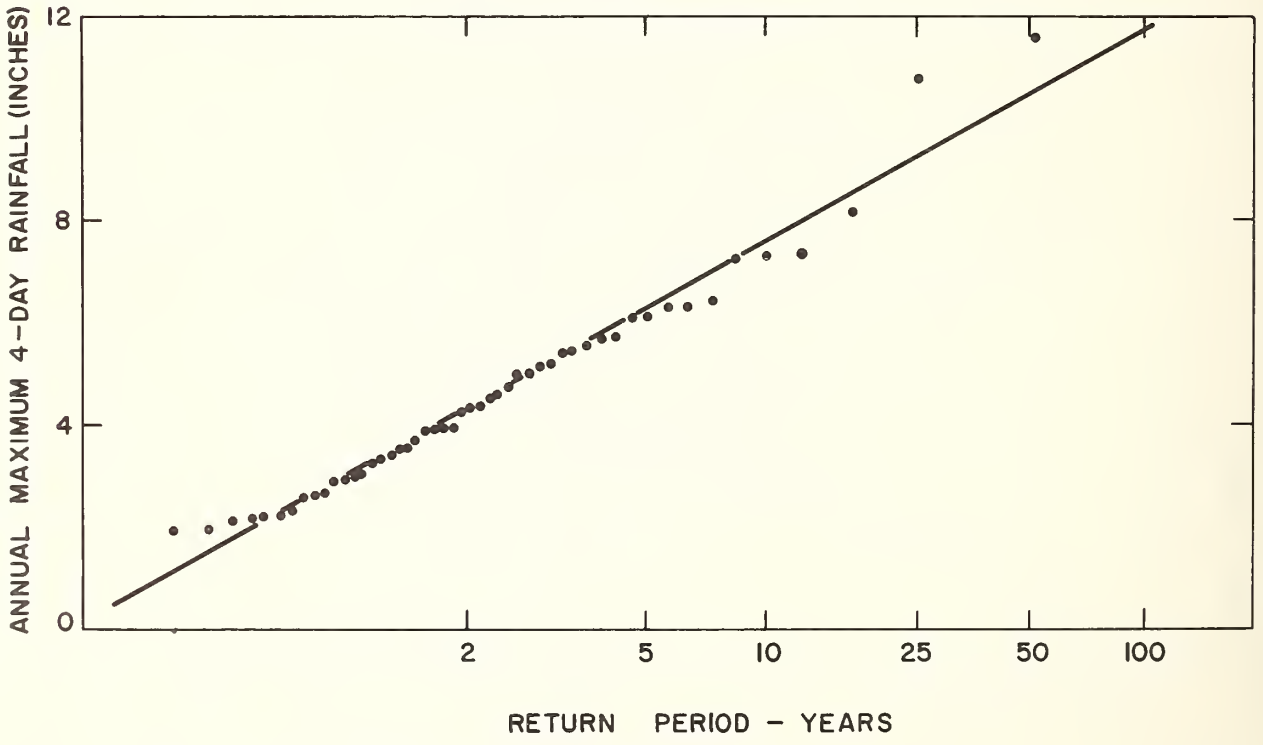

Figure 6.--Gumbel frequency of annual maximum 4-day rainfall at Fort Worth, Tex., 1912-61.

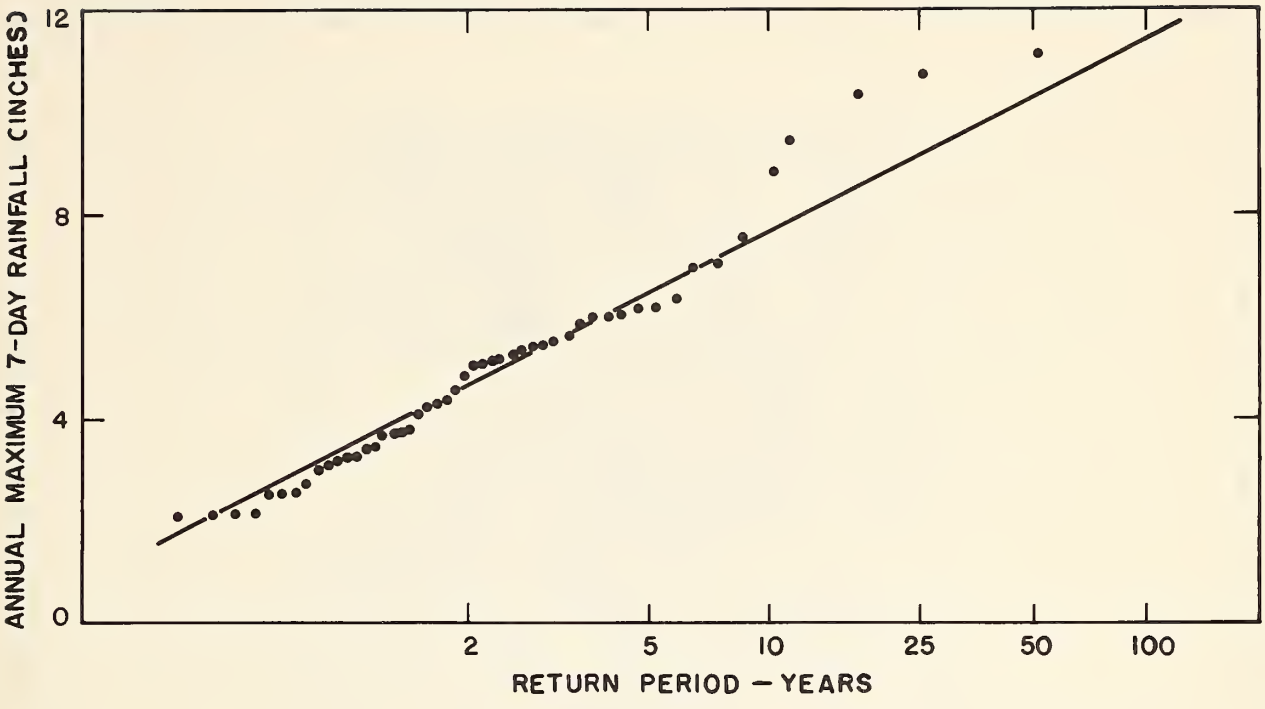

Figure 7.--Gumbel frequency of annual maximum 7-day rainfall at Fort Worth, Tex., 1912-61.

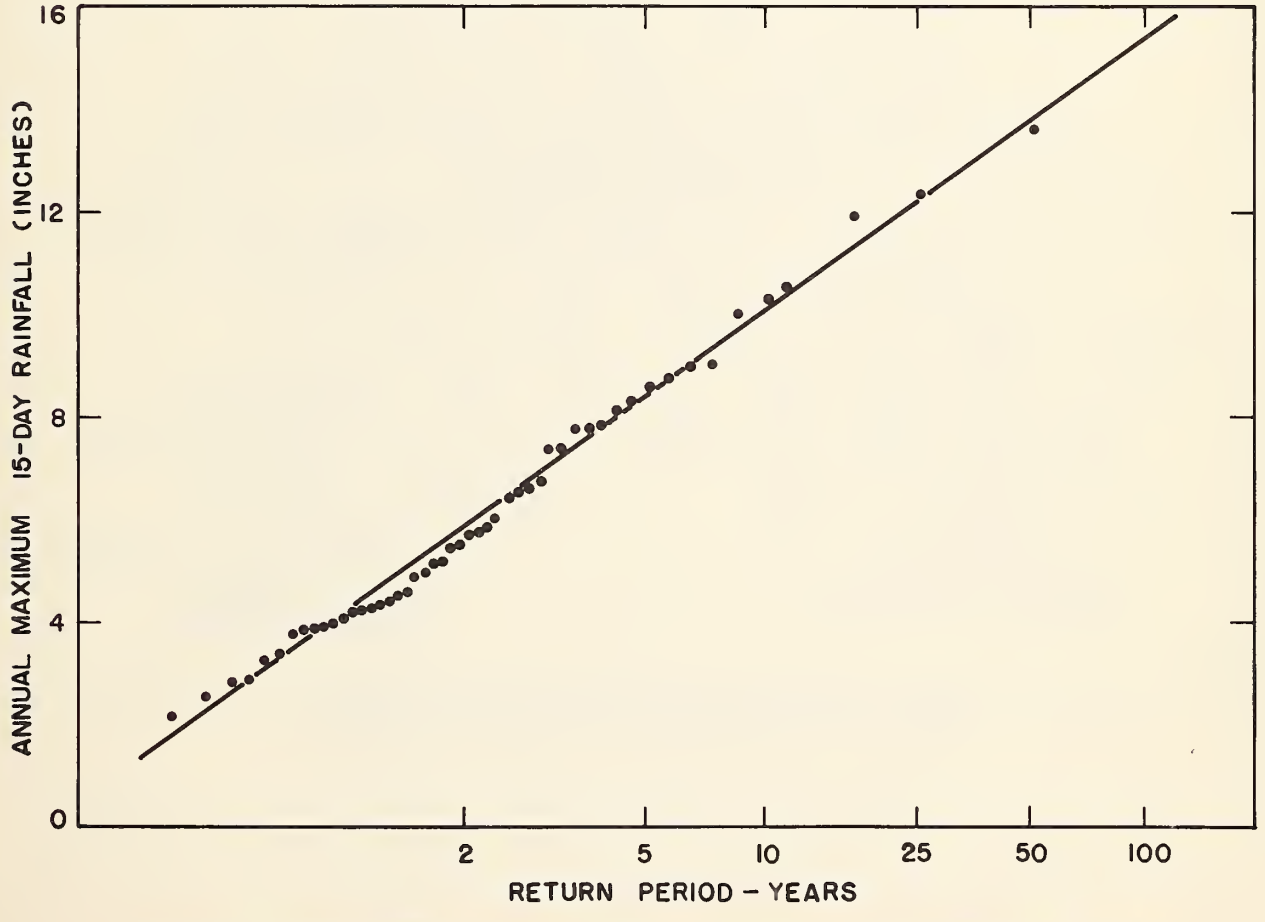

Figure 8.--Gumbel frequency of annual maximum 15-day rainfall at Fort Worth, Tex., 1912-61.

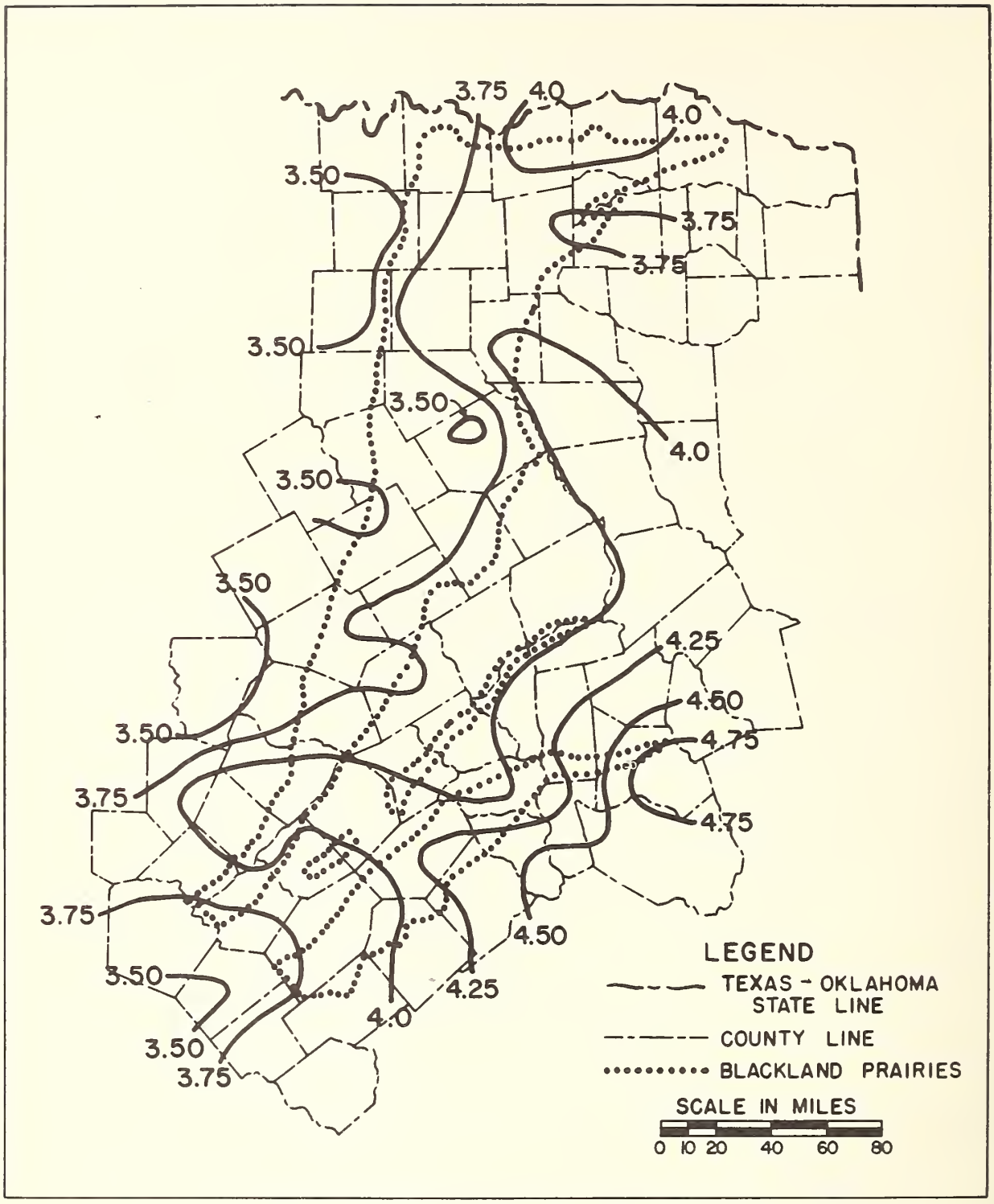

Figure 9.--Probability map, 2-year 1-day rainfall (inches).

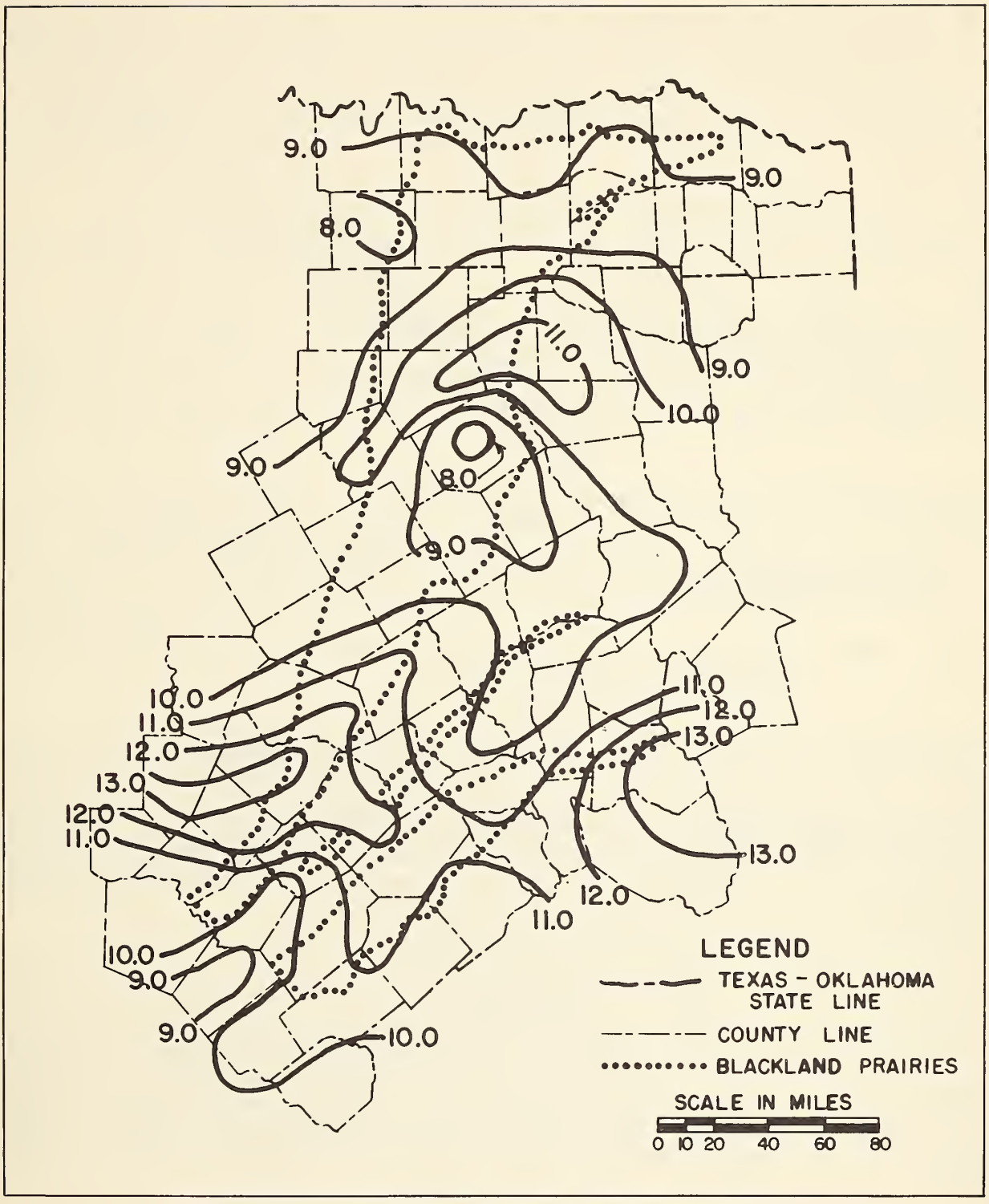

Figure 10.--Probability map, 100-year 1-day rainfall (inches).

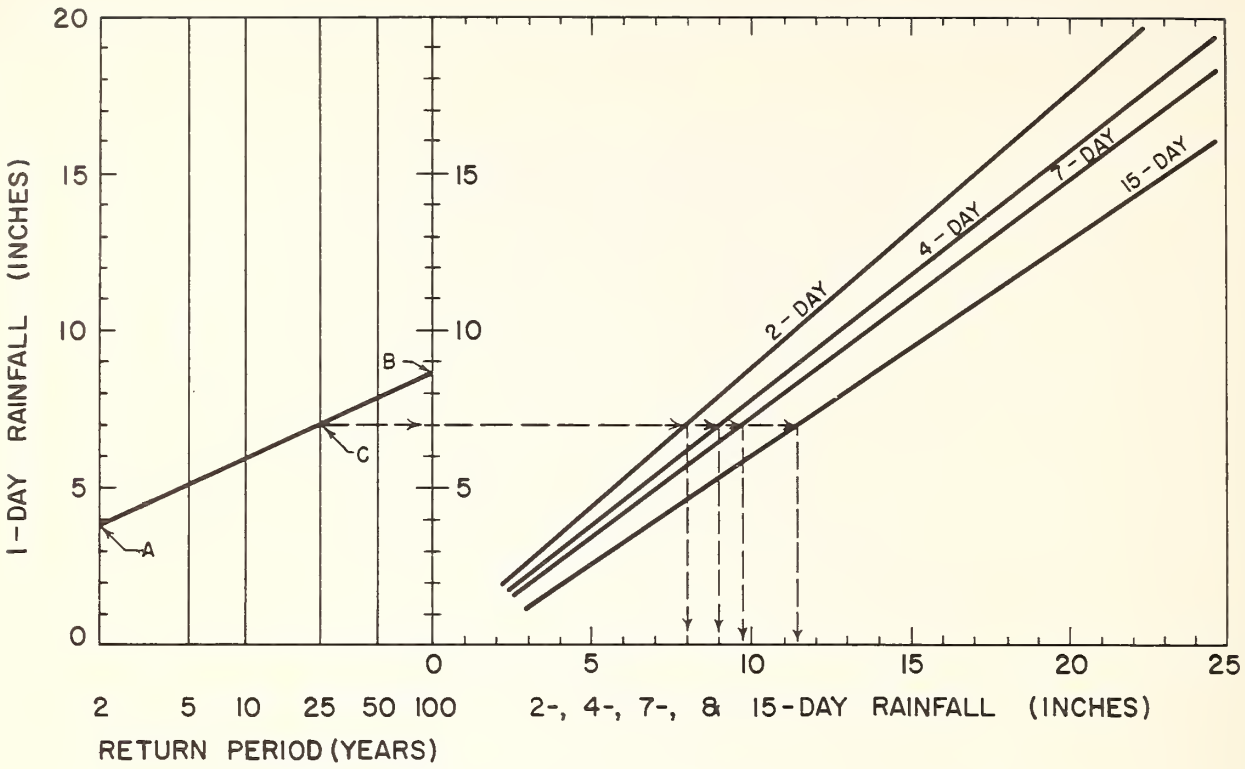

Figure 11.--Relationship between 1-, 2-, 4-, 7-, and 15-day rainfall by return period for the Blacklands of Texas.

the 25-year return period line at point "C" and indicates 7.0 inches for the 25-year 1-day amount. Values for any other return period can be determined in the same manner. To determine 2-, 4-, 7-, and 15-day amounts, a horizontal line is drawn from point "C" towards the right to intersect the duration curves. At the appropriate intersection, the rainfall estimates are found vertically downward on the abscissa, to be 8.1, 9.1, 9.8, and 11.6 inches for 2, 4, 7, and 15 days, respectively. Estimates of rainfall for durations other than those for which lines have been drawn can be made by interpolation. The procedure is the same for each recurrence interval.

DISCUSSION

In developing the relations between 1-day rainfall and the longer periods, consideration was given to storm characteristics that could affect the validity of the relationship. Seasonal variation might be one of these characteristics. Spring, summer, and fall are associated generally with frontal-type cyclonic storms, convective thunderstorms, and tropical storms, respectively, (4, 12) and all were in evidence from Weather Bureau synopses as causing the annual storms.

Most of the storms, and particularly those of longer durations, were associated with frontal movement. The maximum 2-day rainfall was generally produced by frontal-type storms and was usually included as a part of the 4-, 7-, and 15-day duration totals. The maximum annual 1-day rainfall, however, was associated most frequently with the summertime convective thunderstorm. Since surface heating is necessary for convective thunderstorm occurrence, high

summer nighttime temperatures in the Blacklands may be a factor in the increased thunderstorm activity.[3] Local topographic conditions might also influence rainfall amounts. For example, Lowry (5) showed that the Balcones Escarpment along the western Blacklands has an important effect on storm paths and rainfall amounts. Thus, local thunderstorm occurrence, with its scattered summertime pattern and its subjection to topographic influence, may be the explanation for the high and low rainfall areas shown on the 1-day probability maps of figures 9 and 10.

A comparison of the 1-day rainfall probability maps with Weather Bureau data (2) showed that Weather Bureau values were slightly greater for the western Blacklands and slightly less for the eastern Blacklands.

The relations between 1-day rainfall and the amounts for 2 and 4 days as portrayed on figure 11 were checked by comparison with those of Lowry (5). The data are generally in good agreement except that Lowry indicates more rainfall than current determinations for the western Blacklands and slightly less than current values for the eastern areas. Although the data available in 1934 were generally from short-term records and adjustments were made to smooth the lines, the general agreement is reassuring.

Rainfall probability data are not available for durations longer than 5 days. However, the Weather Bureau developed empirical relationships for heavy rainfall from 7-day tropical storms in the Southeastern United States to express the percentage of rainfall accumulation as a function of duration (11). Although tropical storms accounted for only a few annual events determined in this study, a comparison was made with the Weather Bureau data as shown in the following table.

	Percentage of 7-day Rainfall		
	1-day	2-day	4-day
Blacklands	73	83	93
U.S. Weather Bureau	57	75	92

Although the 1-day percentages differ significantly, the 2- and 4-day values are in good agreement. The comparison indicates that long duration storms are of similar characteristics irrespective of storm type.

An evaluation of the analysis was made to determine if the isopluvial increments on the probability maps were justified. A dense network consisting of nine rain gage locations in an 8-square-mile area at Riesel was used in the evaluation procedure. Frequency analyses of annual maximum rainfall data were made for 12 years for 1-, 2-, 4-, 7-, and 15-day durations. The mean coefficient of variation for the 2-year frequency was determined for each duration and the values are shown in the following table.

Duration (days)	Coefficient of variation
1	0.07
2	.10
4	.10
7	.11
15	.14

[3] Weather observers report temperatures at Blackland stations are generally 8° to 10° F. higher at 10 p.m. than in surrounding light-colored soil areas.

The coefficients of variation are relatively small, although the data are from short-term records. The mean 2-year 1-day rainfall from the 47 Weather Bureau gages is 3.9 inches. The variation based on the foregoing table is 0.27 inch. Therefore, the 0.25-inch isopluvial increment on figure 9 appears justifiable.

The procedure for estimating rainfall amounts was evaluated for reliability. Four Weather Bureau locations, Sherman, Waco, San Antonio, and Brenham, were selected for the test. The observed rainfall, i.e., rainfall amounts from the Gumbel frequency, were compared with amounts computed from figures 9, 10, and 11. Comparison of theoretically computed and graphical estimates of 2-year and 100-year rainfall amounts, by duration, at four locations, is shown by figure 12. Two of the 40 points shown in the figure are not within a ±10 percent error band. These two points, both for a 7-day duration, are within ±15 percent. The results are reliable on the basis of the comparisons made.

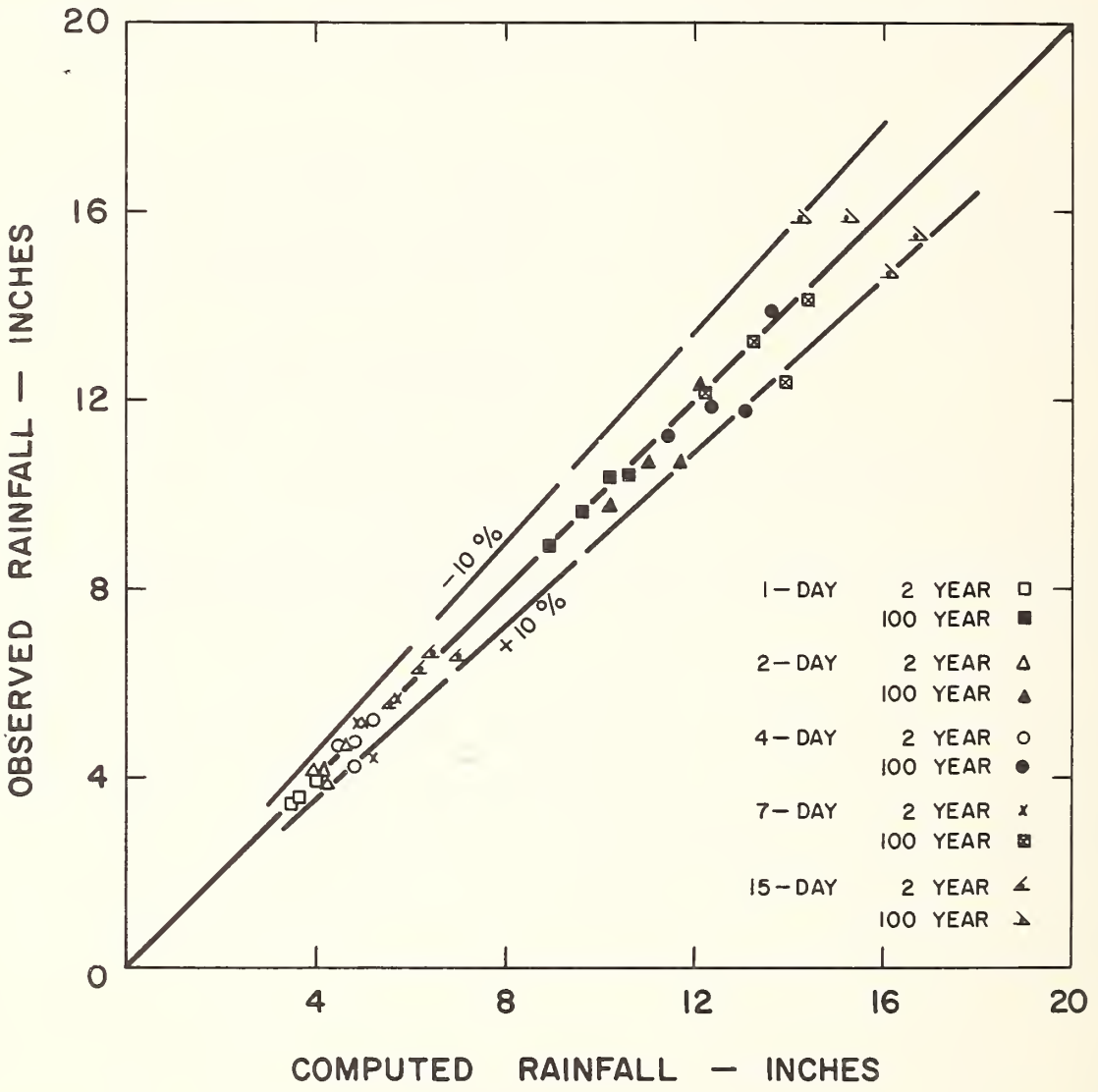

Figure 12.--Comparison of theoretically computed and graphical estimates of 2-year and 100-year rainfall amounts at four locations in the Blacklands of Texas.

SUMMARY

A frequency analysis was made of 50 years of Weather Bureau rainfall data in the Blacklands of Texas. Durations of 1-, 2-, 4-, 7-, and 15-day periods were selected for analysis to provide probability of sequential storm recurrence. Comparisons were made with published data for 1-, 2-, and 4-day durations. The probable rainfall amounts for the long durations are realistic and valid. Although the period of record is relatively long, the possibility exists that the extreme rainfall experienced at a few reporting stations may in time also occur at other locations. Due to the sparse rain gage network used, hundreds of years of record would be required in order to experience the extreme "chance" occurrence thunderstorm at all locations.

Graphical relations between the various durations were made by recurrence interval. Graphical interpolations between 2-, 4-, 7-, and 15-day periods can be made for other durations as desired.

LITERATURE CITED

(1) Godfrey, C. L., Oakes, Harvey, and Smith, R. M.
1960. Soils of the Blackland Experiment Station. Tex. Agr. Expt. Sta. Misc. Pub. 419, 11 pp.

(2) Hershfield, D. M.
1961. Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Paper 40, 115 pp.

(3) _____
1961. Estimating the probable maximum precipitation. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 87(HY5): 99-116.

(4) Linsley, R. K., Jr., Kohler, M. A., and Paulhus, J. L. H.
1949. Applied hydrology. 689 pp. McGraw-Hill Book Co., Inc., New York, Toronto, and London.

(5) Lowry, R. L., Jr.
1934. Excessive rainfall in Texas. Texas Reclam. Dept. Bul. 25, 149 pp.

(6) Kotz, S., and Neumann, J.
1963. On the distribution of precipitation amounts for periods of increasing length. Jour. Geophys. Res. 68(12): 3635-40.

(7) Potter, W. D.
1949. Simplification of the Gumbel method for computing probability curves. Soil Conserv. Serv. SCS-TP-78, 22 pp.

(8) Snedecor, G. W.
1946. Statistical methods. Ed. 4, 485 pp., The Iowa State College Press, Ames, Iowa.

(9) U.S. Department of Agriculture
1911-40. Weather Bureau climatological data, Texas section.

(10) U.S. Department of Commerce
1941-61. Weather Bureau climatological data, Texas section.

(11) _____
1958. Rainfall intensity - frequency regime. Part 2--Southeastern United States. Weather Bur. Tech. Paper 29, 51 pp.

(12) _____
1960. Generalized estimates of probable maximum precipitation for the United States west of the 105th Meridian for areas to 400 square miles and durations to 24 hours. Weather Bur. Tech. Paper 38, 66 pp.

(13) Yarnell, D. L.
1935. Rainfall intensities - frequency data. U.S. Dept. Agr. Misc. Pub. 204, 68 pp.

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